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AUTHOR(S):

Ishizaki, Ryuji; Hata, Hiroki; Shoji, Tatsuo

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Statistical properties of fluctuation for charged fine particles in an AC trap

Ryuji Ishizaki[1], Hiroki Hata[2], Tatsuo Shoji[3]

[1] *Faculty of Integrated Human Studies and Social Sciences, Fukuoka Prefectural University, Tagawa 825-8585, Japan*

[2] *Graduate School of Science and Engineering, Kagoshima University, Kagoshima 890-8580, Japan*

[3] *Graduate School of Engineering, Nagoya University, Nagoya 464-8603, Japan*

There is a wide variety of many-body systems governed by long-range interactions, such as galaxies, colloids, and clouds of charged fine particles in an atmosphere. Most plasmas in nature and in the laboratory are weakly coupled, with Coulomb coupling parameter $\Gamma \ll 1$. However, the collective properties of dust particles are an interesting subject of basic plasma physics because dust particles are usually strongly coupled, with $\Gamma > 1$, since they are highly charged.

We have investigated the behavior of charged fine particles confined for a long time in an AC dipole electric field (AC trap) at atmospheric pressure[1]. The experimental device applies an AC voltage (60-200 Hz, several kilovolts) to a ring electrode (15 mm in diameter) placed between an upper glass board electrode coated with a conductive film (indium tin oxide) and a lower metal electrode. Fine silica particles (SiO2, a few tens of micrometers in diameter) are charged by applying a high voltage to the electrode; the particles are confined in a simple AC trap consisting of ring and parallel plate electrodes at atmospheric pressure.

In our experiment, charged fine particles exhibit stable motion against air resistance for several weeks or more. Both periodic motion and "irregular motion" have been observed, depending on the frequency and amplitude of the AC electric field[2, 3, 4, 5]. However, it has not been confirmed that the "irregular motion" observed in our experiment is chaotic.

Before undertaking experimental and theoretical research on the behavior of charged fine particles experiencing strong Coulomb many-body interactions in an AC trap, we have clarified the behavior of a single particle in the trap. The conditions for confining charged fine particles by an AC electric field are theoretically obtained from the linear stability of the fixed points and periodic points of an idealized electric field model (Mathieu's equation). An energy dissipative term should be included since there is air resistance in our experiment. The addition of a small positive damping term increases the area of stability in parameter space, and only fixed points exist as stable solutions[6]. The emergence of irregular motion by charged fine particles in our experiments, therefore, cannot be explained by Mathieu's equation with an energy dissipative term. The potential $U(r, \theta, z, t)$ generates a rotational diffusion of chaotic orbits and the transition from ballistic to diffusive motion was observed in the Mean Square Displacement (MSD) of θ[7, 8, 9, 10, 11, 12]. The distribution function $f(\tau)$ for the lifetime of angular unidirectional motion was exponential. This exponential distribution is produced by chaotic switching between clockwise and anti-clockwise rotations of orbits on the xy-plane. The time-correlation function $C(\tau)$ of v_θ also has an exponential decay form as a consequence of the lifetime distribution function $f(\tau)$. The scaling function of the MSD of $\theta(\tau)$ is derived using the correlation time τ_c of $C(\tau)$.

The collective properties of dust particles are an interesting subject of basic plasma physics. We have also clarified the behavior of charged fine particles under a strong Coulomb many body-interactions in AC trap. The center of gravity of a two-particle system is a stable fixed point and the motion in relative coordinates is periodic for a large coefficient of friction. The center of gravity of a two-particle system is a stable periodic point and the motion in relative coordinates is periodic for a small coefficient of friction.

The center of gravity of three-particle system is a stable fixed point, and the motion in relative coordinates is periodic for a large coefficient of friction. The center of gravity of three-particle system is a stable periodic point for a small coefficient of friction. We have observed a chaotic motion in relative coordinates for a small coefficient of friction.

We would like to talk about the statistical properties of fluctuation for charged fine particles in an AC trap.

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References

[1] W. Paul and H. Steinwedel, Zeit. Naturforsch, 89, 448 (1953) .

[2] R. F. Wuerker, H. Shelton and R. V. Langmuir, J. Appl. Phys. **30** 342 (1959).

[3] J. Hoffnagle, R. G. DeVoe, L. Reyna and R. G. Brewer, Phys. Rev. Lett. **61** 255 (1988) .

[4] R. Blumel, C. Kappler, W. Quint and H. Walther, Phys. Rev. **A40** 808 (1989) .

[5] R. G. Brewer, J. Hoifnagle, R. G. DeVoe, L. Reyna and W. Henshaw, Nature **344** (5) 305 (1990).

[6] J. H. Taylor and K. S. Narendra, SIAM J. Appl. Math. **17** No. 2 343 (1969).
D. J. Acheson, Proceedings: Mathematical and Physical Sciences **448** No. 1932 89 (1995).

[7] T. Geisel and J. Nierwetberg, Phys. Rev. Lett. **48** 7 (1982).

[8] S. Grossmann and H. Fujisaka, Phys. Rev. **A26** 1779 (1982);
H. Fujisaka and S. Grossmann, Z. Phys. **B48** 261 (1982).

[9] S. Grossmann and T. Thomae, Phys. Lett. A **97** 263 (1983).

[10] H. Koga, H. Fujisaka and M. Inoue, Phys. Rev. A, **28** 2370 (1983).

[11] G. Zumofen and J. Klafter, Phys. Rev. **E 47** No. 2, 851 (1993).

[12] S. Miyazaki, Prog. Theor. Phys. Supplement No. 161 270 (2006).